CORNELL AERONAUTICAL LABORATORY, INC.
4455 GENESEE ST. BUFFALO 21, N.Y.

# RESEARCH TRENDS

VOL. 1, No. 1
FALL 1953

PUBLISHED
QUARTERLY

by GIFFORD BULL

# Research in STALLED FLIGHT*

Ever since the days of the Wright Brothers, stalls have been responsible for a disconcerting proportion of airplane accidents. Stalls result from a fundamental characteristic of an airplane wing: Enough lift to support the weight of an airplane can be obtained by flying fast with the wing inclined at a small angle to the oncoming air, or by flying slowly with the wing inclined at a larger angle. It is advantageous to land and takeoff at a low speed, since then the operation is inherently safer, and the runway requirements may be reduced. As the airplane is flown more slowly, the angle at which the wing meets the air (angle of attack) must be increased. Unfortunately, above some critical angle, usually about 15°, the air ceases to flow smoothly over the wing and breaks away from the surface in eddies. The wing is then said to be stalled. It must be understood that a stall is due to the way the air flows over the wing, and has nothing to do with whether the engine stops running.

When the stall occurs, the lift on the wing decreases sharply and the airplane starts to drop. The drag becomes high and the power required to make the airplane fly level becomes large. Even worse, the airplane becomes highly unstable, and the effectiveness of the controls becomes small. This combination makes the airplane essentially uncontrollable, and it usually rolls off to one side or the other and enters a spin. Normal unstalled flight can be regained by pushing the nose down to decrease the angle of attack below the critical or stalling angle. If the airplane is high enough this is perfectly feasible, but if it is low the ground gets in the way. All this trouble occurs because the pilot, in a perfectly sound desire to fly safely, accidentally flies a little too slowly.

*The work covered in this article was carried out for the Air Force under Contracts W33-038 ac-17002 and AF 33(038)-10480.

FIGURE 1
The Fairchild PT-26 is the airplane used for research in stalled flight. The mast and booms visible on the aircraft are a part of the special test instrumentation.

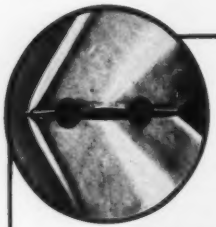
Stalls can also be produced at higher speeds, by making the angle of attack too high when making a sharp turn or recovering from a dive, or by encountering a sufficiently strong upward gust.

Pilots avoid stalling by maintaining some extra speed, so the airplane never needs to reach the stalling angle of attack. The landing and takeoff performance then usually suffers, because the airplane is never flown as slowly as it is actually capable of being flown. The penalty in landing and takeoff performance is considered more acceptable than the risks involved in operating too close to the stall.

Designers can provide an airplane in which the dangers of the stall are greatly lessened by resorting to such stratagems as limiting the ability of the elevator control to make the airplane fly at angles of attack too near the stall; by designing the wing to make the inboard parts stall first (thereby retaining some rolling stability and aileron control); by applying leading edge slots, which delay the stall on part or all of the wing; or by other similar means. Unfortunately, schemes of this nature usually compromise some other desirable characteristics of the airplane, such as low drag, structural simplicity, or freedom from icing troubles.

## THE PROBLEM

The question then is: Are there any other reasonable approaches to the problem of stalls? Can we expect to make any major improvement in the motion of the stalled airplane? The first step would appear to be a theoretical examination of the problem to see what work might yield the most profitable result. There are several obstacles to a theoretical investigation. For example, when a lifting surface is stalled, the change of lift corresponding to an increase in angle of attack becomes more or less irregular and usually becomes negative. Since the derivation of many of the stability characteristics of the airplane depends on the interrelationship between lift and angle of attack, doubt is immediately cast on the possibility of treating the problem theoretically except by laborious step-by-step numerical calculations. Even though modern computing machines can handle calculations of this type with dispatch, another problem occurs when an attempt is made to find suitable numbers to put into the equations. There is very little quantitative information on the characteristics of a stalled airplane.



## THE COVER

The photo insert at the top of the cover page shows the wave pattern produced by supersonic air flow over a double-wedge airfoil model. The three main wave patterns may be readily observed. The bow-shaped shock wave at the front results from a slight blunting of the leading edge of the airfoil. An expansion wave, produced by the air streaming over the sharp corner of the double-wedge model, may be seen fanning out at the center of the photograph. At the rear can be seen the shock wave and wake set up as the air converges at the trailing edge of the model. The method of mounting the model in the tunnel produced the two dark circular areas in the photograph. The airflow is at a Mach number of 1.3 or a velocity of about 850 miles per hour.

## THE SEEDS ARE PLANTED

Since stalling has always been an important problem, a considerable amount of work already has been done. The British research people undertook an extensive investigation of the stall in the 1920's and arrived at a comprehensive basic understanding of what caused the motion of a stalled airplane. In this country, the National Advisory Committee for Aeronautics investigated the details of the breakdown of the airflow at the stall and tested many lateral control devices in an effort to find the type that would provide the most control at the stall. The NACA also carried out flight and wind tunnel tests to determine the manner in which the stall occurs and progresses over the wing surface. This information is also an important aid in understanding airplane actions which signal the onset of a stall, such as buffeting of the airplane or the controls, small uncontrollable oscillations, or a radical change in control forces. Such behavior warns the pilot that the airplane is about to stall in time for him to do something about it and avoid the stall.

About six years ago, the Cornell Aeronautical Laboratory became interested in determining why a stalled airplane behaves as it does. The Laboratory had carried out extensive studies of the dynamic stability characteristics of unstalled airplanes, and it was felt that some of this experience could be applied to the problem of the motion of a stalled airplane. The development of a usable theory of the motion of the stalled airplane, coupled with a quantitative explanation of what factors caused the motion, would help in determining the stall characteristics of an airplane before it was built. Steps could then be taken to provide satisfactory characteristics without the expense of modifying the finished airplane.

The fact was recognized that the pilot is not concerned with the manner in which the flow breakdown occurs, or what causes the motion. He is interested primarily in how the airplane behaves at the stall, and in what he can do about it.

## CONQUEST BY FLIGHT

Airplanes differ in the way they behave at the stall, and a considerable part of this difference is caused by the rapidity with which the stall progresses over the wing. In some airplanes the lift curve (lift versus angle of attack) appears discontinuous, but of course the airplane has inertia and hence its motion cannot be discontinuous. Consequently, the possibility of securing meaningful information from flight tests appeared reasonable, in spite of peculiar fluctuations in the forces and moments applied to the airplane. The motion of a stalled airplane is influenced by so many interacting factors that flight tests seemed to be the best way to investigate the problem without neglecting some important factor.

The work was started under Air Force sponsorship and the Laboratory purchased a Fairchild PT-26 to use as the test airplane. This type of airplane was selected because it is a representative modern shape, a wind tunnel model exists, and a PT-26 is economical to operate. The first flight tests were made to see if the motion was reproducible, or if it was random and there-

fore not predictable. Exploratory tests indicated that the motion was in fact reproducible if careful attention was paid to the conditions at the time of the stall. Furthermore, with considerable practice and concentration in the test flights, the lateral motion could be separated from the longitudinal motion.

The longitudinal motion was investigated first, since it is usually simpler to handle than the lateral motion, both in theory and experiment. A preliminary flight program indicated that the motion of the airplane resembled that of a spring-mass-damper system closely enough so that the equation of this simple system proved a good concept around which to organize the flight data.

## FLIGHT IN THE STALL

Most airplanes nose down sharply when stalled, and the test airplane was no exception. For experimental purposes, it was desirable to be able to maintain a steady stall, so the airplane's stabilizer was modified to provide enough nose-up pitching moment to keep the airplane in a steady stall. Flight tests were then conducted in which measurements were made of the airplane's response to sudden elevator motions and of its behavior in a steady stall. Typical of the flight data obtained in these tests is the lift curve shown in Figure 2. It is noteworthy that there is relatively little scatter in the data taken above the stall, indicating that reproducible results can be obtained from tests in stalled flight. From these tests the longitudinal characteristics of the stalled airplane were determined. Of particular interest was the discovery that an unexpectedly long time lag, of the order of one second, occurs between a change in angle of attack and the resulting change in lift. In unstalled flight, this lag is a few hundredths of a second.

The lateral motion of the airplane could not be studied by the same techniques, since the airplane was highly unstable laterally in the stall, and a steady condition to start from could not be obtained. Furthermore, if by good luck and careful technique a steady condition could be obtained, the least disturbance would cause the airplane to roll off and start spinning. The technique decided upon was to stabilize the stalled airplane by an autopilot, then measure the response of the stabilized airplane to a sudden control motion. The characteristics of the autopilot could be measured and taken into account, making possible the determination of the characteristics of the basic airplane.

## AN UNEXPECTED DEVELOPMENT

A Sperry A-12 autopilot was modified to suit the purpose and installed in the airplane. It is necessary to provide the proper signal inputs and autopilot characteristics to stabilize the airplane. The proper signal inputs could have been chosen quite accurately if airplane characteristics had been known, but these characteristics could not be determined unless the autopilot was operating properly. Preliminary calculations indicated some likely quantities to use as inputs, and the installation was made sufficiently flexible to allow the signals to the autopilot to be varied in flight. A great deal of flight testing was necessary to arrive at the proper combination of signal inputs and autopilot characteristics, but eventually the system was developed to the point where it successfully stabilized the stalled airplane and kept it from rolling off into a spin. At present, data flights are being conducted in which the autopilot is engaged, the

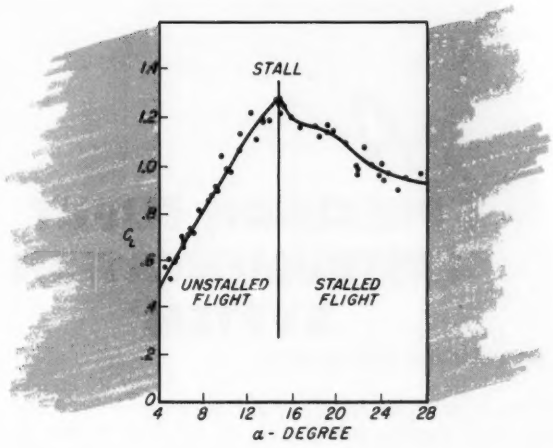



FIGURE 2
The Lift Curve for the PT-26 airplane as determined from four flights.

airplane stalled, and its response to lateral control motions is measured. Analysis of the flight records should provide quantitative information on the stability characteristics of the airplane in the stall.

As sometimes happens in research work, a tail was developed which bids fair to wag the dog. The autopilot was put in the airplane initially to enable the airplane characteristics to be measured. If it can prevent the airplane from rolling off and spinning, it may be useful as a device for improving the stall characteristics of airplanes in general use. Since many airplanes have autopilots installed for other reasons, it would be quite simple to detect the approach of a stall by an angle of attack measuring instrument, and switch the autopilot over from inputs and autopilot characteristics used in normal unstalled flight to the ones necessary to keep the airplane stable in the stall. If the airplane can be made to behave reasonably well in the stall, it may be possible to exploit this hitherto useless regime of flight.

## NEW POSSIBILITIES

The technology of stabilized stalled flight still presents more problems and research opportunities than it has solutions. The work to date suggests several practical applications of stalled flight to the imaginative engineer. Presently impossible but advantageous turning and landing maneuvers may some day be flown by airplanes which are designed to use the resources of a stabilized stall. In fact, stabilized stalled flight may be useful in any situation in which it is desired to:

1. Prevent loss of control in an inadvertent stall.
2. Utilize the absolute maximum lifting potentialities of an airplane.
3. Perform rapid descents without picking up excessive speed.
4. Obtain high drag at low speeds, as in minimizing the landing run of airplanes.

The present trends in airplane design accentuate the stalling problem and add urgency to research on the stall.

*REPORTS*

"Determination of the longitudinal stall dynamics of a PT-26 airplane," Bull, G. and Campbell, G. (Feb. 1950).

"Analytical investigation of lateral motions of an airplane at the stall—with and without autopilot," Bull, G. and Campbell, G. (April 1949).

# A PRECISION FLIGHT INSTRUMENTATION SYSTEM*

by MAURICE KAUSHAGEN

Every kind of vehicle from the simplest to the most complicated requires instruments or sensing devices so that the operator can tell where he is going and how the machinery is working. At one extreme, the youngster pilots his tricycle down the sidewalk after he learns to accumulate "navigational information" and can use it to control the vehicle. At the other extreme, the modern transport airplane pilot with his one or more aides uses a complex structure of instrumentation and control equipment (sometimes numbering more than a thousand items) in guiding his aircraft safely and efficiently to its destination.

In the case of the tricycle, the problem is quite simple because it is slow-speed and two-dimensional; further there is considerable freedom in the choice of the exact path. If the vehicle rolls off the sidewalk, there are only a few tears and a bruised knee. As the complexity of the vehicle and the urgency of the mission increase, the consequences of inaccurate or ill-used information become more serious. The navigation problems for ground-based vehicles such as tricycles and automobiles do not include the rather important complications associated with the third dimension encountered in flying. Much of the aircraft instrumentation, especially for the military, must be incredibly precise, and dependably so, or it is literally not worth carrying along.

## PRECISION IS THE GOAL

The Cornell Aeronautical Laboratory is active in the field of aircraft instrumentation, and this article describes a package of precision measuring and computing devices designed into an accurate and efficient system of instruments. This system is called the Flight Line Computer, and its development has involved fundamental investigations of several physical principles (airflow around the aircraft being the main one), diversified equipment development, and finally extensive precision flight tests at the Laboratory. Figure 1 shows the Navy F9F-2 jet airplane just after take-off with the Flight Line Computer installed in it.

The Flight Line Computer is designed to compute the following five flight variables: angle of attack, angle of side slip, Mach number, true airspeed, and relative air density. Very roughly speaking, in level flight, angle of attack refers to how much the airplane is inclined upward, and angle of side slip refers to how much the airplane is turned sideways to the direction of motion. Even though they usually are small, both angles are important. The somewhat more familiar term, Mach number, is the ratio of aircraft speed to the speed of sound. Since the speed of sound varies with temperature, true airspeed can be obtained from Mach number and temperature. Relative air density refers to density at altitude compared with standard conditions at sea level.

These variables may appear somewhat outside the region of immediate interest, since they are not usually measured in conventional personal aircraft or even in most commercial or military planes. Actually some of these quantities are measured with such precision that the resulting special accuracy is of little direct use to the pilot. Instead these Flight Line Computer outputs provide precision information required for closely controlled automatic flight, and are not even presented to the pilot as dial indications. The present day growth in operating speed and performance of airplanes has necessitated the precise measurement of these more elusive, specialized variables.

*The work covered in this article was carried out for the Navy Bureau of Aeronautics under Contracts NOa(s)9289 and NOa(s)12058.

FIGURE 1
Navy F9F-2 jet airplane just after take-off, carrying the Flight Line Computer.

## THE NEED

To explain the importance of measuring each of the five flight variables would be a lengthy task, but some general insight into the usefulness of the Flight Line Computer can be gained by examining just one of the variables such as angle of attack. Unlike most other kinds of transportation (except perhaps skiis) an airplane can consistently point in a different direction from the one it is going. While an airplane flies level, it may be flying slowly with the nose inclined upward (somewhat above the horizontal) at a high angle of attack, or it may be flying faster with the nose pointing nearly straight ahead at a small angle of attack. The deviation depends on the weight of fuel and pay load as well as speed, altitude, temperature, and other things. There are important relations among angle of attack and cruising efficiency, wing stalling speed, automatic control, and military fire control. Thus, quantitative flight knowledge of angle of attack, one of the key quantities measured by the Flight Line Computer, can find important application in the high speed aircraft of today. Similar discussions can be presented for the other four Flight Line Computer outputs.

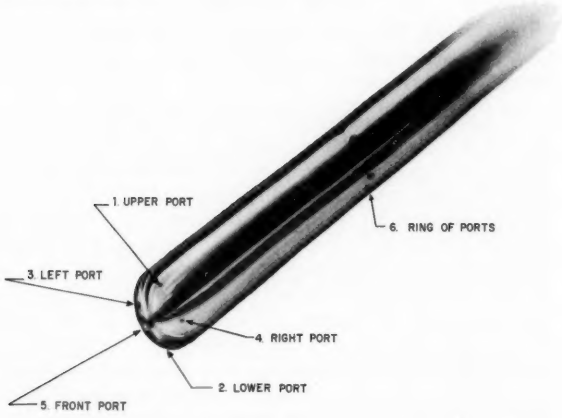



**FIGURE 2**

**The vector pitot tube. Note the six pressure ports; port number 6 is actually a ring of 12 interconnected holes.**

Angle of attack could be measured by a sort of weather vane sensitive to the direction of air flow. In flight, however, such a vane would be undesirably sensitive to vibration, acceleration, and flutter; hence a special type of multi-hole pitot tube called the vector pitot tube is used instead (See Figure 2). A temperature-measuring probe and this special vector pitot tube provide temperature and the six pressures needed to compute angle of attack, angle of side slip, Mach number, true airspeed, and relative air density.

The computation process uses known definite relations among all these pressures and desired results, but these relations are rather thoroughly interwoven. The designer of a Flight Line Computer must decide exactly what "known" relations he will use, that is, exactly where each item of information shall be carried and what will be done with it there.

Although this planning leads to an information flow chart such as shown in some detail in Figure 3, it is necessary in this discussion to observe only the three main steps:

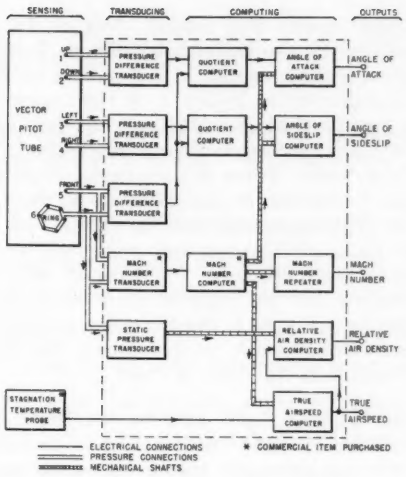



**FIGURE 3**

**Block diagram or flow chart of the Flight Line Computer.**

1) Each input physical quantity is "sensed" by a device that responds to the particular effect (e.g. air pressure) to be measured.

2) The physical quantity is "transduced" or converted into a more manageable form of energy (e.g. an electric voltage) proper for computation.

3) Finally the transduced inputs are combined in a computer with other transduced inputs to provide meter readings or control signals which are the desired outputs.

Sometimes a desired combination can be made to occur in the transducing operation (e.g. pressures can be added or subtracted in the transducer instead of afterwards).

Continuing with the example of angle of attack, we soon find that the sensing element placed in the air stream in the vicinity of the aircraft will not measure the true angle of attack of the airplane because of the distortion of airflow in the vicinity of the aircraft. This distortion is known to be affected by other measurable quantities, such as Mach number and angle of attack itself. After the quantitative effects of these extra influences are determined by theory and by experiment (both wind tunnels and flight), a sequence of mathematical operations can be simulated electronically and electromechanically to obtain true angle of attack of the airplane.

The two sensing elements used in the Flight Line Computer are a specialized pitot tube and a stagnation temperature probe. The ordinary pitot tube is that L-shaped pipe which is usually located somewhere under the nose or wing of the conventional transport airplane. This pitot tube picks out air pressure in holes pointed along and across the airstream blowing past the airplane, so that by measuring these two different pressures in the pitot tube in a particular and precise way, much can be learned about the airflow and hence about airspeed, Mach number, and altitude.

The specialized pitot tube or vector pitot tube measures six important pressures rather than just the two measured by the ordinary pitot tube. It consists of a cylinder with a hemispheric end (very much like a broom

handle both in size and shape). Five of the pressures are measured by the five small holes or pressure ports that are accurately located in the surface of the hemisphere as indicated in Figure 2. A sixth quantity, static pressure or the free air pressure for that altitude, is measured by a ring of inter-connected holes farther back along the cylinder. When this precisely machined vector pitot tube is inclined in the direction of the wind, five important flight quantities can be determined by measuring the six available pressures accurately and combining their outputs properly. The logic of this composite determination can be depicted in a block diagram or flow chart as in Figure 3. The sequence of the main computational steps (though not their exact methods) can be traced through on this type of chart.

All preliminary flight data for the Flight Line Computer with the exception of the outside air temperature come from the pressures measured in the vector pitot tube.

## DECEIVING SIMPLICITY

Although the principle of operation is straightforward enough, such vector pitot tubes had not been thoroughly developed for dependable precision at the start of the Flight Line Computer program. Therefore the Cornell Aeronautical Laboratory carried out a rather extensive experimental investigation involving theoretical studies and wind tunnel and flight tests to determine the quantitative performance of various vector pitot tubes as influenced by Mach number, detailed shape of the nose,

**FIGURE 4**
**Vector pitot tubes and the temperature probe.**

and apparently minor features of construction. Figure 4 shows several experimental sensing elements; the tube chosen for the Flight Line Computer is pictured at the extreme right, although in the reproduction not all of the small holes show clearly. While the shapes of the various vector pitot tubes of Figure 4 appear rather simple, their special features are matters of precision of fabrication and accuracy with which the shape-performance relations are determined. The temperature probe shown at the upper left of Figure 4 is a commercial product purchased for this project.

## CUSTOM BUILT

The outputs of the vector pitot tube in the form of pressures and differences between them must be converted into electrical or mechanical signals by pressure transducers. Commercially available pressure transducers are not suited for use with this vector pitot tube because of the special characteristics needed. These characteristics are associated with the relatively small pressure to be measured, and the requirements for extremely accurate operation under the severe conditions involving speed range, altitude range, and acceleration encountered in high performance aircraft.

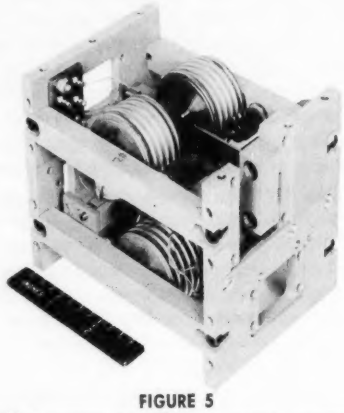


**FIGURE 5**
**Partly disassembled pressure transducer to convert pressures into electric signals.**

A partly disassembled pressure transducer developed at Cornell Aeronautical Laboratory for this project is shown in Figure 5. Pressure differences are converted to electric signals by special differential transformers. By proper orientation of the combinations of elements, undesirable effects of temperature changes and of airplane acceleration in gusts and turns are removed. This particular model has a repeatability corresponding to approximately 0.01 pounds per square inch or one quarter of one per cent of full scale. Sensitivity and stability are especially important because the pressures available in a pitot tube generally change with the square of the airplane velocity. Thus for a typical military aircraft with an operating range of 7 to 1 (say 560 to 80 knots) the transducer operating range should be 49 to 1 with acceptable accuracy throughout.

## RAPID RESPONSE

The computer is an electromechanical device. It consists of amplifiers, motors controlled by the amplifiers, and special precision electromechanical computing elements driven by the motors. The computer system accepts electrical signals from the pressure transducers and the temperature probe. On the basis of the theoretically and experimentally determined mathematical relationship, it delivers the five final Flight Line Computer outputs with accuracy and with the rapid dynamic response necessary in maintaining accuracy during the airplane's most violent maneuvers.

For the flight evaluation phase of the project, the system consisting of sensing element and the transducer-computer chassis shown in Figure 6 (cover removed) was installed in the F9F-2 Navy jet airplane shown just after take-off in Figure 1. The vector pitot tube can be seen protruding a short distance ahead of the nose of the aircraft. This particular location was chosen because it provides a position of minimum airflow distortion. It also is free from interference with other flight equipment, and gives the sensing elements a protected position above

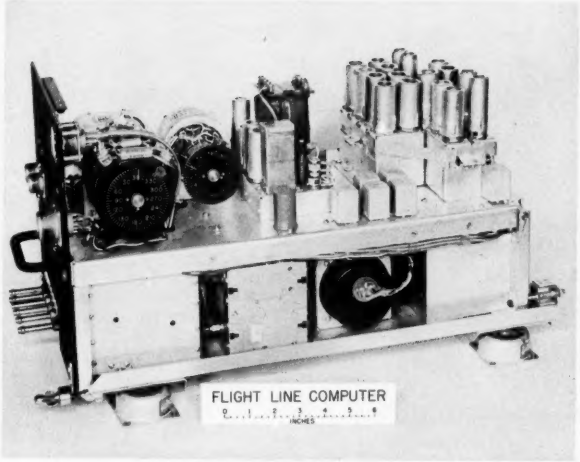



**FIGURE 6**
**Transducer and computing chassis of the Flight Line Computer.**

the working level of the deck crew. The computer chassis was installed in the nose section of the aircraft a short distance behind the vector pitot tube.

During exacting evaluation flights, the aircraft was flown throughout its speed and altitude range while aircraft and computer system performance were carefully recorded. Present-day flight experiments employ methods of great flexibility and effectiveness in recording and analyzing performance of airborne devices. Specific information on Flight Line Computer performance cannot be revealed here but is contained in the technical reports listed below. It can be said, however, that upon completion of this evaluation, the Flight Line Computer could properly be called a "precision flight instrumentation system" for modern aviation.

*REPORTS*

"A symposium on flight data measuring equipment for aircraft fire control system," Greatbatch, W. (September 1952).

"Wind tunnel and theoretical investigations of position error variation with angle of attack and Mach number for two typical fuselage sensing locations," Bogdan, L. and Segel, L. (June 1952).

"Flight line computer—Phase A report," Bogdan, L., Segel, L. and Woolard, H. (January 1951).

"Instantaneous flight line computer and dive pullout computer," (September 1949).

# *Introducing*

# RESEARCH TRENDS

This issue of RESEARCH TRENDS marks the start of a new undertaking. Through the medium of this publication, and within the limitations imposed by security, we will attempt to highlight some of the varied applied research activities in which the Laboratory is engaged. In preview, some of the general areas of research and development we plan to treat will include: aerodynamics, armament, electronics, flight research, helicopter research, instrumentation techniques, materials and structures, operations research, propulsion, automotive and aviation safety research, and wind tunnel testing.

If you should desire more technical detail concerning specific research projects described in this and subsequent issues of RESEARCH TRENDS, you are invited to request copies of the pertinent technical reports and papers that will be listed directly following each article.

As a regular feature of this publication, a general listing will also be presented of current Laboratory technical reports and papers.

Although normally we will be able to handle promptly all requests for publications listed in RESEARCH TRENDS, some delay will necessarily be encountered in those instances where distribution of a report is contingent upon prior approval of the contract sponsor.

## *About the Authors . . .*

**GIFFORD BULL** is a Project Engineer in the Flight Research Department, and has been associated with the stall research investigation since coming to C.A.L. in 1948. He has solely carried out all flight tests in the program and probably has flown more hours in stalled flight than any other pilot.

Mr. Bull received a Bachelor's degree in Mechanical Engineering and a Master's degree in Aeronautical Engineering from Cornell University. A licensed pilot, he has over fifteen years of flying experience, including a period during World War II in which he flew the "Hump" in C-46s and C-47s between India and China for the China National Aviation Corporation. Mr. Bull has previous experience with the Sperry Gyroscope Company, and Lear, Incorporated. He is a member of the Institute of the Aeronautical Sciences, and Tau Beta Pi.

**MAURICE KAUSHAGEN** is Assistant Head of the Physics Department of C.A.L. He came to the Laboratory in 1946 from the Naval Ordnance Laboratory where he had been concerned with under water ordnance. At C.A.L. he has been associated with the Flight Line Computer project for seven years, as a member of the group, later as project engineer, and finally as supervisor. He took an active part in the research, development, wind tunnel and flight tests, in fact accompanying C.A.L.'s chief pilot, John Seal, on test flights of an early model of the instrumentation system in an F7F "Tigercat" fighter.

Mr. Kaushagen obtained his A.B. in physics from Concordia College. He holds a Master's Degree in physics from the University of Illinois. He is a senior member of the Institute of Radio Engineers, and a member of the Institute of Aeronautical Sciences, American Physical Society, American Association for Advancement of Science, and Sigma Xi. He is the Laboratory's representative on the Radio Technical Committee for Aeronautics.

# Recent C. A. L. PUBLICATIONS

Requests for copies should be directed to the Editor.

**"An analysis of accuracy requirements for inertia characteristics used in aircraft response calculation," Notess, C. B. (March 1953)**

A variety of flight maneuvers under critical conditions were investigated for six representative aircraft.

**"An approach to the determination of higher harmonic rotor blade stresses," Daughaday, H. and Kline, J. (March 1953)**

The designer is presented with means for estimating the magnitude of higher order bending moments and with a tentative analysis indicating the cause to be variations in downwash over the rotor disk.

**"An exploration of numerical filtering techniques," Fleck, J. T. and Fryer, W. D. (May 1953)**

Numerical filtering is introduced as a method for extending to arithmetic or digital processes the familiar frequency domain approach of electrical filter theory, and unique possibilities for the application of numerical filtering in analogue systems are suggested.

**"A review of the problem of external aircraft noise," Swartzel, K. D., *Aeronautical Engineering Review* (March 1953)**

The factors involved in the problem of noise from aircraft are presented in logical form and the difficulties encountered in attempting to cope with them are noted.

**"Bipolar logarithmic Corona-current amplifier," Chapman, S. and Bogdan, L., *Electronics* (January 1953)**

A simple electronic circuit is described which uses two 9004 biased diodes back to back and which has a logrithmic response to dc signals of both polarities from $3 \times 10^{-9}$ to $3 \times 10^{-4}$ amperes.

**"Cementation of metals — hard aluminum alloy surface study," Smith, L. W. and Stewart, R. S. (February 1953)**

The potentialities of dispersion hardening of aluminum, magnesium and steel with refractory hard particles were investigated.

* **"Fire emergency control system," Naulty, H. (April 1953)**

The purpose of this survey was to study the sequence of operations necessary to stop both reciprocating and turbo aircraft engines as rapidly as possible in the event of a fire.

**"IBM card programing computer techniques," Houser, H. D. and Trabka, E. A. (April 1953)**

This report summarizes three aids to IBM C.P.C. computations: checking program by machine, making logical decisions by use of a five field floating decimal board, and polynomial approximations by machine.

**"Interpolation servomechanisms," Fleck, J. T. (April 1953)**

An interpolation system was investigated for generating a continuous output approximating a polynomial input which is observed only at discrete intervals.

**"Materials determine aircraft design," Porter, P. K., *Industrial Laboratories* (June 1953)**

A brief review is presented of work that has been carried out at C.A.L. in the general field of materials with emphasis upon chemistry, metallurgy, plastics and heat transfer problems.

**"Notes on aircraft dynamic stability testing and analysis techniques," Breuhaus, W. O. and Segel, L. (April 1953)**

This paper presents a brief historical sketch of recent full-scale dynamic stability flight testing with typical data obtained; it discusses transient and steady state response measurement techniques, and describes the various flight test analysis methods with emphasis on the longitudinal motion.

**"Notes on the static longitudinal stability and control of aircraft," Breuhaus, W. O. (Reissued March 1953)**

A rather complete summary is presented of the fundamentals of static longitudinal stability and its relationship to certain aircraft handling qualities.

**"Protection of the human head from blows delivered by a flat surface," Dye, E. R., *Safety Education* (April 1953)**

A discussion is presented of the characteristics that padding materials should possess for protecting the human head against impact blows.

**"Radar and the collision problem," Brantley, J. Q., Jr., *Skyways* (June 1953)**

A discussion is presented of the potentialities of continuous wave radar as a collision warning device.

**"Reverse-flow and variational theorems for lifting surfaces in nonstationary compressible flow," Flax, A. H., *Journal of the Aeronautical Sciences* (February 1953)**

A reverse flow theorem for compressible nonsteady flow, valid within the limits of linearized theory, is derived.

**"Science and technology," Furnas, C. C., *Modern World Politics* (1953)**

A critical review is presented of the role of pure and applied science in the industrial and military power of nations.

**"Summary of the methods suggested for determining longitudinal dynamic response characteristics of an airplane to a gust input," Lappi, U. O. (May 1953)**

A brief description and discussion is given of three methods which have been suggested as possible techniques for calibrating an airplane for gust inputs.

**"The next fifty years," Furnas, C. C., *Aeronautical Engineering Review* (June 1953)**

Aeronautical development trends during the next fifty years are predicted.

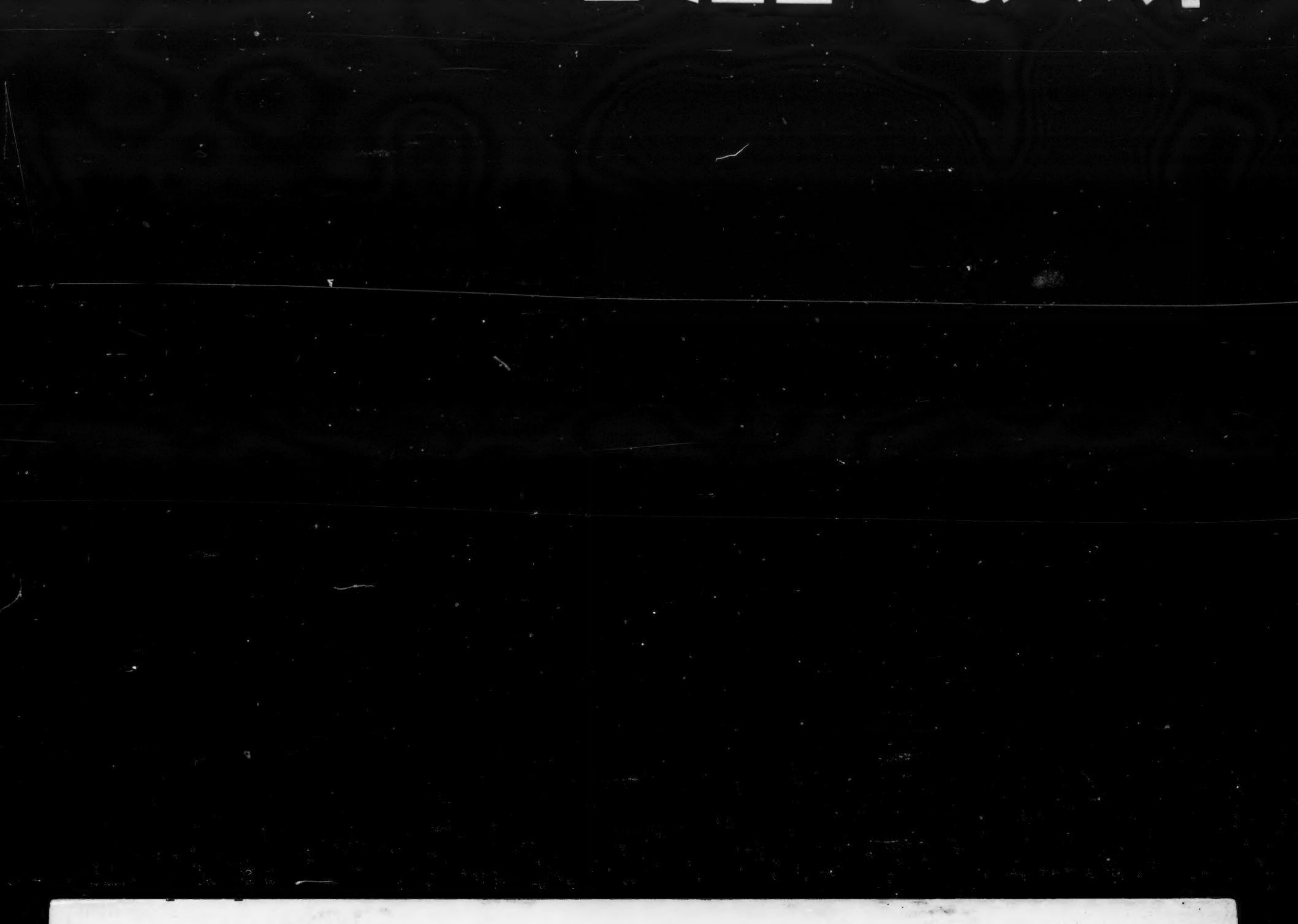
* **"The noise field around a B-47 airplane," Kamrass, M. and Swartzel, K. D. (April 1953)**

The field of noise created by a B-47 airplane flying at full power is described and methods are developed which are useful in determining the loudness that would occur on the ground in the vicinity of any flight path of the airplane.

**"The pressure distribution on low aspect ratio wings in steady or unsteady incompressible flow," Lawrence, H. R., *Journal of the Aeronautical Sciences* (March 1953)**

A method is presented for estimating the distribution of lifting pressures when the chordwise lift distribution is known.

**"The structural tail load problem — theory, tests and criteria," Koegler, R. K., *I. A. S. preprint* (January 1953)**

A review is presented, based on unclassified literature, on the theories, tests and criteria involved in the structural tail load problem on conventional subsonic aircraft.

* Distribution of these publications requires approval of the sponsor.